Method and standard for selecting elite nut trees of Korean pine

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Abstract: The fruit-bearing quantities of nut Korean pines (*Pinus Koraiensis*) of natural stands in Changbai Mountain, Xiaoxing'an Mountain, and Wanda Mountain and of artificial forest in Hegang area of Heilongjiang Province were investigated and measured by seed collection of singletree during 1988-1998. In order to evaluate the elite nut tree of fructification, the characteristics of fructification of Korean pine, including, the fruit-bearing quantity, output of seed, quantity of cone, cone size, seed size, the ratio of null seed by solid seed, seed percentage of cone, rate of the cones infested with pest, and fruit-bearing index, etc., were analyzed with the variance analysis, multiple comparison and stepwise regression to obtain the contribution ratio of each fruit-bearing factor to fruit-bearing quantity. The multiple correlation factors and the partial correlation factors for fruit-bearing quantities of Korean pine were determined for different geographical areas, and the cone length, thousand-grain-weight, and the seed percentage of cone were considered as important indices for selection of elite trees. The method of modified weighted coefficients was adopted to select the elite nut trees of Korean pine. Standards for selecting elite nut trees from the natural stands and artificial forest of Korean pine were established. This study could provide selection method and standard of elite nut trees for setting up seed orchard of Korean Pine.

Key words: Korean pine; Elite nut tree; Selection method
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Introduction

Korean pine (*Pinus koraiensis*) is one of the valuable tree species in northeast of China. Its timber, seeds, barks, leaves and roots have higher industrial values; especially its edible seeds are of value to health care. With the upgrading of people's living standard and industrialization, the demand for Korean pine nut will continuously increase.

For selection of elite trees of candidacy, we should commence from their characteristic of phenotypic variability and regard the fruit-bearing quantity, cone length, seed percentage of cone and the thousand-grain-weight as factors. To select elite nut trees of Korean pine is not only helpful in utilization of Korean pine clones, but also benefit to the breeding that elite tree is taken as seed parent, in addition, it could also provide material foundation for setting Korean pine seed orchard in northeast of China.

This paper is aimed at setting up a standard of elite trees of candidacy for establishing seed orchards of Korean pine. The selected elite trees must have high yield in nuts, which have high content of oil and are fit for food production as well as other industries (Liu 1998).

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Material and method

The selection of the natural elite stands of Korean pine was carried out in Changbai Mountain, Xiaoxing'an Mountains and Wanda Mountains. In the hazelnut-Korean pine forest type, the elite stands were determined according to the standard of the elite stand for natural Korean pine forest (Suo 1982; Zhang 1999). Fixed sample plots were set and seed collection by single plant was done in the elite stands. The characteristics of fruit-bearing of Korean pine (Ma 1996) were measured, including the output of seed, quantity of cone, cone size, seed size, the ratio of null seed by solid seed, seed percentage of cone, rate of the cones infested with pest, and the fruit-bearing index, etc.. In order to evaluate the elite stands of fructification, with above factors, we carried out the variance analysis, multiple comparison and stepwise regression and obtained the contribution ratio of each fruit-bearing factor to fruit-bearing quantity. Any standard trees whose indexes of all the fruit-bearing factors exceed the average values of forest stands were decided as the elite trees of candidacy. The modified weighted coefficient method was adopted in selecting elite trees, and the candidacy tree with highest weight value was considered to be the elite trees.

In accordance with the characteristics of fruit-bearing and high yield of Korean pine (Lu 1999), we selected the elite nut trees in plantation of Korean pine in Hegang City of Heilongjiang Province.

Results and analysis

Selection of elite nut trees in natural forest

Selection of elite stands

Through variance analysis and LSR test for the seed output quantities of six sample plots in Changbai Mountain area, we could clearly find that the fruit-bearing quantities of No.4 and No.5 sample plots are obviously higher than those of other sample plots ($F_{0.05}$=7.378>$F_{0.05}$ (6.84)=2.22) (See Table 1). The variance analysis and LSR test for fruit-bearing indices of five sample plots in Xiaoxing'an Mountains showed that the fruit-bearing indices of No.1 and No.3 sample plots are significant higher than those of other sample plots [$F_{0.05}$=4.78>$F_{0.05}$ (4.60)=1.38] (See Table 2).

Table 1. The multiple comparison (LSR) of the elite forest stands in Lushuihe Forestry Bureau in Changbai Mountain

Sample No.	A	x_1- x_j	x_2- x_j	x_3- x_j	x_4- x_j	x_5- x_j	x_6- x_j
4(x_1)	3.915	0					
5(x_2)	3.892	0.023	0				
13(x_3)	2.838	1.077	1.054	0			
20 (x_4)	2.254	1.661*	1.638*	0.584	0		
23 (x_5)	2.154	1.761*	1.738*	0.684	0.100	0	
25 (x_6)	1.431	2.484**	2.461*	1.407	0.823	0.723	0

Note : A is the average fruit bearing quantity of parent trees (Kg).

"*" means significant difference

"**" means very significant difference

Table 2. The multiple comparison (LSR) of the elite stands of fructification in Lilin Experimental Forest Farm in Xiaoxing'an Mountains

Sample No.	B	x_1- x_j	x_2- x_j	x_3- x_j	x_4- x_j	x_5- x_j
1(x_1)	1.74	0				
3(x_2)	1.70	0.04	0			
4(x_3)	1.62	0.12	0.08	0		
2(x_4)	0.96	0.78*	0.74*	0.66	0	
5(x_5)	0.94	0.80*	0.76*	0.68	0.02	0

Note : B is the average bearing index of parent trees.

"*" means significant difference

The bearing characteristics of different natural climatic areas

The bearing characteristics of Korean pine were difference in different natural climatic areas. The cone length, cone width and thousand-grain-weight were compared between Changbai Mountain, Xiaoxing'an Mountain and Wanda Mountain. The result showed there exists significant difference between them (see Table 3). Therefore, it is suggested that the standard for elite nut tree of Korean pine should be separately drawn up according to different natural geographic regions. The values of cone length, cone width, thousand-grain-weights, and shape index of the cone from Lushuihe Forestry Bureau in Changbai Mountain (Jilin Province) were all higher than those of the cones from Lilin Forest Farm in Xiaoxing'an Mountain (Heilongjiang Province).

Table 3. The differences of fruit-bearing characteristics in different geographic areas

Geographic areas	Sample amount	D.B. H /cm		Cone length /cm		Cone width /cm		Thousand-grain-weight /g		Cone shape index*	
		x	Sx	x	Sx	x	Sx	x	Sx	x	Sx
Chanbai Mountain	12	55.61	8.688	12.84	1.38	7.856	0.556	589.11	114.98	0.604	0.029
Xiaoxing'an Mountains	40	53.73	7.596	11.81	1.35	5.798	0.531	406.60	73.26	0.494	0.016
Wanda Mountains	45	61.14	11.86	11.40	1.09	6.840	0.520	490.00	89.44	0.579	0.024
1-2$t_{0.01}$=2.647		td	0.127	td	3.414**	td	17.157**	td	8.817**	td	7.333**
1-3$t_{0.01}$=2.646			2.461		5.408**		8.787**		5.747**		1.604
2-3$t_{0.01}$=2.645			3.407		0.641		9.208**		4.701**		6.684**

*Cone shape index =Cone width/Cone length

Analysis of fruit-bearing factors

For evaluating the contribution ratio to the fruit-bearing quantity and bearing index with giving by phenotypic attributes of individual nut Korean pine, we carried out the multiple linear regression and the variables include the tree height, breast height at diameter, cone length, cone width, seed length, seed width, thousand-grain-weight, the ratio of null seed by solid seed, seed percentage of cone, and the rate of cone infested with pest. The calculated results are as follows.

The multiple correlation factors for fruit-bearing quantity of the Korean pine in Changbai Mountain are seed output (0.662925) and fruit-bearing index (0.6018303), and the partial correlation factors of the seed output include tree height (–0.224673), diameter at breast height (0.4488496), cone length (0.2670359), cone width (–3.276989E-02), seed length (–0.3747353), seed width (0.114591), thousand-grain-weight (0.2483343), seed percentage of cone (0.593043), the ratio of null seed by solid seed (–3.714981E-02), damaged rate by pest (–3.73489E-02).

The multiple correlation factors for fruit-bearing quantity of Korean pine in Xiaoxing'an Mountains are seed output (0.5302665) and fruit-bearing index (0.5063505), and the partial correlation factors of seed output include the diameter at breast height (–0.3703589), cone length (0.1231404),

cone width (–0.3975265), thousand-grain-weight (0.152427), seed percentage of cone (0.3484573), rate of the cones infested with pest (–0.2608272).

Cone length (w_1), thousand-grain-weight (w_2) and seed percentage of cone (w_3) are considered as important indices for selection of elite trees. We distribute these three partial correlation coefficients by percentage and determine the contribution ratio as follows:

For Changbai Mountain, the contribution ratio of cone length is 0.241, thousand-grain-weight 0.224, and seed bearing percentage is 0.535, while for Xiaoxing'an Mountains, the contribution ratios of these factors are 0.197, 0.244, and 0.559 respectively, same as those of Wanda Mountains.

The tree whose indices of all the fruit-bearing factors were higher than the mean values was selected as elite tree of candidacy. The indices of fructification of the candidate elite trees in different areas were shown in Table 4. The weight coefficients of the candidate elite trees were calculated by the following equation and sequenced from big to small.

$$I = W_1 \frac{P_1}{\overline{P_1}} + W_2 \frac{P_2}{\overline{P_2}} + W_3 \frac{P_3}{\overline{P_3}} \cdots\cdots W_n \frac{P_n}{\overline{P_n}}$$

where I is weight coefficient, $\overline{P_1}$ is mean value of forest stand, P is individual mean, and W is contribution ratio.

Table 4. Indices of candidacy elite trees in different areas

Area	Sample Number	Cone length /cm	Cone width /cm	TGW /g	Seed percentage %	NGP /%	Fruit-bearing index	Seed Length /cm	Seed width /cm	RNS	Injured rate by pest /%	Index of selection
Changbai	4-63	13.5	8.5	607.6	43.6	12.5	1.73	1.56	1.06	12.5	37.4	1.069
Mountain	5-34	14.5	9.0	682.8	43.3	2.6	2.02	1.48	1.04	2.6	16.8	1.227
	5-71	13.8	7.8	696.6	41.1	2.8	1.14	1.57	1.09	2.8	17.6	1.077
	5-31	13.7	8.4	657.7	58.4	4.0	1.38	1.56	0.95	4.0	20.4	1.293
	Mean	12.8	7.8	589.5	39.8	6.3	1.11	1.50	1.00	6.3	30.7	
Xiaoxing'an	1-11	12.2	5.6	434.0	43.5	-	2.50	-	-	-	-	1.029
Moutains	1-12	12.6	5.6	426.0	46.9	-	2.90	-	-	-	-	1.080
	1-19	12.3	6.3	416.0	42.8	-	2.10	-	-	-	-	1.015
	1-25	13.4	5.6	501.0	49.6	-	2.70	-	-	-	-	1.117
	Mean	11.8	5.6	406.0	42.5	-	1.34	-	-			
Wanda	11-21	12.8	7.1	687.5	-	-	0.94	-	-	-	-	-
Mountains	11-22	12.9	7.5	552.5	-	-	0.94	-	-	-	-	-
	11-27	12.5	6.8	501.3	-	-	1.71	-	-	-	-	-
	11-28	12.2	7.3	597.5	-	-	1.03	-	-	-	-	-
	Mean	11.6	6.8	510.2	-	-	0.70	-	-	-	-	-

Note: TGW--Thousand-grain-weight; NGP-- Null grain percentage; RNS--The ratio of null seed by solid seed..

Standard for elite nut tree of natural Korean pine forests

The most considered economic index as to the elite trees of Korean pine is fruit-bearing quantity or fruit-bearing index. From the matrix composed of fruit-bearing factors and fruit-bearing quantity, it can be seen that the cone size and seed size present most distinctive correlations with thousand-grain-weight, the seed percentage of cone is correlated with fruit-bearing quantity (R=0.4880**), and the correlative coefficient of the seed size with the bearing index is R=–0.3891*. With exception of this, the rest coefficients correlate tenuously with fruit-bearing quantity. Hence, elite nut trees should be selected from the trees with genetic characteristics of big size and high yield, thus, we use the selection index and the fruit-bearing index to establish the standard of elite nut trees of Korean pine for the geographic regions of Changbai Mountain, Xiaoxing'an Mountains and Wanda Mountains in northeast of China (See Table 5). The best year for selection of elite trees is bumper harvest years as for the highest potential genetic attributes of breeding can be displayed in harvest years, but we should not give up selection in non-leap years and bad harvest years. No matter in bumper harvest years or bad harvest years, the bearing attributes of elite trees are superior to that of common trees. Therefore, the elite trees should be evaluated in successive three years and screened from candidate trees.

Selection of elite nut trees in artificial Korean pine forest

In Hongqi Forest Farm (No. 4 plot of compartment 60) of Hegang City, seed collection was done by single plant, totally 33 trees, in the 27-year-old pure plantation of Korean pine in 1995. We made correlation analysis according to fruit-bearing characteristics and make up the correlative matrix (see Table 6), and the average values of fruit-bearing factors of single plant are illustrated in Table 7.

Table 5. Standards of elite nut trees of natural Korean pine

Area	Grade of stand	Tree age/a	Bark type	Sex	Grade of Stocking	Bearing index	Mean selecting index	Cone length /cm	Cone width /cm	Thousand-grain-weight /g	Seed percentage /%
Changbai Mountain	Superior bearing	≤200	Rough bark	Female	I	>1.30	1.290	>13.5	>8.5	>650	>45
Xiaoxing'an Moutains	Superior bearing	≤200	Rough bark	Female	I	>2.50	1.10	>12.5	>6.0	>500	>45
Wanda Mountains	Superior bearing	≤200	Rough bark	Female	I	>1.50	1.15	>13.0	>7.0	>550	>45

Notes: The standards of this Table are applicable for seed years.

Table 6. Correlation coefficient of fructification for plantation of Korean pine in Hegang City (Xiaoxing'an Mountain)

	Cone length	Cone width	Seed length	Seed width	Thousand-grain-weight	Seed percentage of cone	Kernel-bearing percentage	Number of cone	Cone weight	Seed weight
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	y_1	y_2
x_1	1.000	0.4307	-0.0253	-0.4118	0.5610	0.2517	0.4025	-0.0310	0.2148	0.3048
x_2		1.000	0.4856	-0.1017	-0.1265	0.3501	0.2345	-0.5817	-0.3354	-0.2726
x_3			1.000	0.3239	0.2695	0.3237	0.0714	-0.3268	0.2799	-0.2278
x_4				1.000	0.6628	0.1510	0.2741	-0.1875	-0.3072	-0.1477
x_5					1.000	0.1250	0.0026	-0.2392	-0.3050	-0.2013
x_6						1.000	0.2360	-0.3907	-0.2605	0.0238
x_7							1.000	-0.4210	-0.3267	-0.1547
x_8								1.000	0.9054	0.7782
y_1									1.000	0.9024
y_2										1.000

Table 7. Fruit-bearing characteristics of Korean pine plantation

Sample Tree	Cone number	Cone weight /kg	Average cone length /cm	Average cone width /cm	Seed weight /kg	Average seed length /cm	Average seed width /cm	Thousand grain weigh /g	Kernel-percentage /%	Oleiferous ratio /%
Average	7.00	1.84	13.6	8.1	0.66	1.62	1.03	703.5	40.6	68.14
15	8.00	2.60	14.8	8.1	1.20	1.62	1.06	732.5	46.2	68.62
145	40.00	8.20	13.5	7.4	3.51	1.70	1.04	722.5	42.9	69.10

By correlatively analyzing the correlative matrix of x to y_1 in Table 6, the partial correlative coefficients are concluded:

x_1 (cone length)=0.300312

x_5 (thousand-grain-weight)=0.332263

x_2 (cone width)=0.4139944

x_6 (seed fruit bearing percentage)=0.1264976

x_3 (seed length)=-0.1527133

x_7 (kernel fruit bearing percentage)=6.280998E-02

x_4 (seed width)=-0.2356255

x_8 (cone number)=0.9120558

The multiple correlative coefficient is R=0.954512. Each contribution percentage of fruit bearing is determined by according to partial correlative coefficient.

$W_1(x_1)$=0.1532 $W_2(x_2)$=0.2112

$W_3(x_3)$=0.1694 $W_4(x_4)$=0.4652

The No.15 tree and No.145 tree, whose values of x_1, x_2, x_3, x_4, x_5, x_6, x_7, and x_8 exceed the mean value forest stand (Table 7), were selected as the most elite trees. We used the modified weight coefficient equation to calculate the weight coefficients of No.15 tree (I=0.99137) and No. 145 tree (I=3.17726). No. 15 tree has taken the lead in fruit-bearing quantity in the whole forest stand since 1992. Though the values of cone length and cone width of No.145 were smaller than the means of forest stand, its output of seed is 5 times more than the mean value and fruit bearing quantity is the highest among all plants of the forest stand, with the highest weight coefficient, thus we listed it in the candidacy elite trees.

The cones of Korean pine are differentiated in pre-maturity and late-maturity by mature period. The premature cones are small in size, large in quantity, light in thousand-grain-weight, with high oleiferous percentage, and applicable for oil manufacture. In contrast, the late-maturing cones are big in size (19-20 cm in length and 9-10 cm in width),

heavy in thousand-grain-weight (835 g), and their seeds are big (1.9 cm in length and 1.2 cm in width), with big kernel, low oleiferous percentage, and flavor taste, and applicable for edible manufactures. In the consideration of all these facts, the standards for elite nut trees of Korean pine have been drown up by different economic purposes and listed in Table 8.

Table 8. The standard for elite trees of Korean pine plantations

Tree age /a	Cone type	Selectivity index	Cone number	Cone length /cm	Cone width /cm	Thousand-grain-weight /g	Oleiferous percentage /%
25	Big cone	>.09	>8	>14.5	>8.0	>750	>70
25	Small cone	>3.0	>40	>13.5	>7.0	>700	>65

Notes: selectivity index is the sum of all weight coefficients.

Conclusion

The establishment of standards for elite nut trees of Korean pine is the basis for constructing seed orchard. The standards and methods for selecting elite nut trees in both natural forest and artificial forest of Korean pine advanced based on a large quantity of investigations and researches have been proved through practice to be applicable. However, but this research only focus on phenotypic option, the management of seed orchard should be strengthened and the trace identification of the filial generation shall be timely processed.

To select elite trees should commence from their variability of phenotypic properties under the circumstances of fruit-bearing quantity, cone length, seed-bearing percentage and thousand-grain-weight. The contribution ratio of each bearing factor to its own fruit-bearing quantity is concluded by variance analysis, multiple comparison and stepwise regression, and the modified weight coefficient equation is finally established.

References

Liu Li .1998. Analysis of developing activity and foreground of Korean pine nut ecological trees [J]. Journal of Forest Survey and Design, (4): 45-46. (in Chinese)

Lu Yifang.1999. Effect of thinning on fructification quantity of Korean pine nut trees [J]. Forest Science and Technology, 1:13-14.

Ma Abin.1996. Selection of high quantity Korean pine: Theory and practice of northeast forest cultivation [M]. Beijing: China Forestry Publishing House, p28-31. (in Chinese)

Suo Qisnan. 1982. Study on fructification regulation of natural changbai larch [J]. Forest Science, (4):347-356. (in Chinese)

Zhang Shujun. 1999. Primary study on outstanding clone selection of Korean pine nut trees [J]. Journal of Forest Survey and Design, (1): 38-39. (in Chinese)